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Correlation of head posture, deep cervical flexor muscle endurance and simple reaction time in young healthy adults

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Abstract

Background and Objectives: Posture associated reduction in the endurance of deep cervical flexor (DCF) muscle endurance may negatively impact the proprioception of the cervical spine. As pertinent proprioceptive feedback is obligatory for rapid processing of visual feedback, visual reaction responses can be delayed with spindle dysfunction associated with poor muscle function. Hence, the aim of this study was to assess a correlation between head posture, DCF muscle endurance and reaction time in asymptomatic young healthy subjects.

Method: Total 260 participants of the age group 18-24 year were recruited. One-time assessment of head posture, DCF strength and reaction time was done. Correlation analysis was done using Spearman Rank Correlation Coefficient (*ρ).*

Result: The results of the analysis indicated a positive correlation between head posture and DCF endurance (r = 0.3541, p < 0.0001), a weak-to-moderate negative correlation between head posture and reaction time (r = -4727, p < 0.0001) and a moderate-to-strong negative correlation between DCF endurance and reaction time (r = -6787, p < 0.0001)

Conclusion: Present study concludes the head posture, DCF endurance and simple reaction time are moderately associated with each other in young healthy adults.

Keywords: head posture, deep cervical flexor, endurance, reaction time, young healthy adults

Introduction

Posture can be described as an attitude assumed by the body, either with support during muscular inactivity, or by the means of coordinated action of many muscles working to maintain stability, or to form an essential base which is being adapted constantly to the movement which is superimposed on it [1]. It represents the body's reaction to the forces of gravity and is maintained through a set interaction between various systems [2]. Posture is a base on which any movement pattern is derived, and poor posture has been recognized as a remarkable contributor to musculo-skeletal dysfunctions [3]. Postural assessment is one of the highlights of physio-therapeutic examination as postural dysfunction has been regarded as one of the most common causes of symptoms in general population [4].

Forward Head Posture (FHP) is characterised with extension of the head and the upper cervical spine (C1 – C2 – C3) with an associated flexion of the lower cervical spine (C4 – C7), resulting in hyper-lordosis [5]. It is one of the most common postural malalignments of the cervical spine and is clinically correlated to various conditions, including soft tissue overloading & cervical pain, headaches, vertebral body disorders, muscle imbalances, scapular dyskinesis as well as temporo-mandibular joint dysfunctions [6]. A significantly high density and contrasting features of the muscle spindles in the deep cervical muscles not only allow substantial accuracy of movement, but also provide sufficient proprioceptive input required for control of head position, movements and eye movement coordination [7].

There are literatures correlating cranio-vertebral angle with cervical range of motion (ROM), strength, endurance and muscle size which conclude that the resultant change in the spatial relationship between the cervical spine and line of gravity due to dysfunctional postures can be predisposing factors to muscular and connective tissue overload, neck pain, reduction in available ROM, endurance as well as size of the muscles [8-11]. It has been well documented that the prevalence of computers, laptops and mobile phones usage is very high in young adults, and hence they are prone to develop poor postural habits, which can overtime cumulate and result in various impairments. There is paucity of literatures available on the relationship between posture, muscle endurance and reaction time in asymptomatic healthy adults as well as the significance of assessing reaction time in clinical practice.

Reaction time can be a forerunner of various activities of daily living (ADL's), and is of great practical significance. Fast reaction times may have benefits, in areas such as sports and recreation, whereas slow reaction times can have detrimental consequences, in areas such as motor vehicle driving and road safety, as well as in professional skills required in various tasks [33]. Reaction time, if altered/reduced, can affect the speed as well as quality of ADL's.

Presumably, there are scares literatures which correlate cervical spine posture with deep cervical flexor muscle endurance and reaction time. Therefore, the purpose of this study is to assess for a correlation between head-neck posture, deep flexor muscle endurance and reaction time in asymptomatic population, which can play a crucial role in prevention and escalation of obvious symptoms in future as well as justify assessment and treatment outcomes for the present symptomatic population.

Aim: To study the correlation of head posture, deep cervical flexor muscle endurance and simple reaction time in asymptomatic young adults.

Objectives

- To assess Head Posture by measuring Cranio-Vertebral Angle (CVA) using Lateral Photography and Markus Bader (MB) Ruler software
- To assess Deep Cervical Flexor Muscle Endurance using the Cranio-Cervical Flexion Test (CCFT).
- To assess Simple Reaction Time (SRT) using Deary-Liewald Reaction Time Task (DLRT) software.
- To find a correlation between Head Posture, Deep Cervical Flexor Muscle Endurance and Simple Reaction Time.

Hypothesis

Null Hypothesis (H0)

- There is no correlation between Head Posture, Deep Cervical Flexor Muscle Endurance and Simple Reaction Time in young healthy adults.

Alternate Hypothesis (H1)

- There is a positive or negative correlation between Head Posture, Deep Cervical Flexor Muscle Endurance and Simple Reaction Time in young healthy adults.

Materials and Methodology

- **Study Design:** Correlational Study
- **Study Duration:** 6 Months.
- **Sample Population:** Asymptomatic Young Healthy Adults.
- **Sampling Method:** Convenient Sampling.
- **Sample Size:** 260
- **Inclusion Criteria:** Young healthy males & females within the age group 18 to 24 years, subjects willing to participate.

- **Exclusion Criteria**
- Present or previous history of neck pain.
- History of cervical spine injury.
- History of cervicogenic headache.
- History of vaso-vagal symptoms.
- History of somato-sensory disorders affecting balance and stability.
- History of surgical interventions in the past.

- **Methods of Measurement**
- Cervical Spine posture was analyzed by Cranio-Vertebral Angle (CVA) using Lateral photography and Markus Bader (MB) Ruler software.
- Deep Cervical Flexor Muscle Endurance was assessed using Cranio-Cervical Flexion Test (CCFT).
- Simple Reaction Time (SRT) was assessed using Deary-Liewald Reaction Time Task (DLRT) software.

- **Study Procedure:** Methods of Data Collection
- **Recruitment of Participants**

  Asymptomatic Young Healthy Adults between the age group 18-24 were recruited for the study on the basis of the inclusion and exclusion criteria. The Study, its need, their role as well as the duration was explained. Written informed consent was taken and demographic data including name, age, gender and dominance was documented.

- **Assessment of Cranio-Vertebral Angle (CVA) [12,13,14]**
- 2 Markers were applied on the subjects, one marking over the C7 spinous process and one over the tragus of the ear.
- A digital camera was placed on a tripod stand, with the height adjusted according to the level of subject's shoulder.

- The subjects were seated on a chair and asked to remain in their relaxed habitual posture. The photograph was clicked against a white background.
- The photograph was then transferred to a computer, where the CV Angle was measured using the MB Ruler Pro Software.
- The Cranio-Vertebral angle (x°) for each subject was documented in a Microsoft Excel® sheet.

- **Assessment of Deep Cervical Flexor Muscle Endurance [15]**
- The Deep Cervical Flexor Muscle Endurance was assessed using Cranio- Cervical Flexion Test (CCFT).
- Pressure Bio-Feedback unit was used (Stabilizer® by Chattanooga).
- The CCFT was performed with the subject in crook lying position with the head and neck in mid-range and the inflatable pressure sensor was placed under the cervical spine. The device was inflated to 20mm hg to fill the lordotic curve of the cervical spine.
- While keeping the head stationary, subjects were asked to flex the upper cervical spine by nodding the head in 5 graded segments of increasing pressures (22,24,26,28,30 mm hg) and hold each for 10 seconds, with 10 seconds rest between each segment.
- The examiner observed and corrected any substitution movements to ensure that all subjects could perform the test correctly. Signs of incorrect performance, such as posterior retraction of the chin to push directly onto the sensor, were corrected during the practice phase.
- Subjects were closely monitored and superficial neck flexor muscle recruitment was discouraged by verbal feedback.
- Subjects were trained for this test; 2 practice sessions were given with rest prior to actual examination.
- Activation score was noted, which was the value at which the subject was able to hold the contraction for 10 seconds.
- If the subject was able to initiate the movement to the desired pressure, but unable to maintain it, the lesser value was documented as the Activation Score.
- The Activation Scores (in mm hg) were documented for each subject in Microsoft Excel® sheet.

- **Assessment of Simple Reaction Time (SRT) [16,17]**
- SRT was assessed using Deary-Liewald Reaction Time Task (DLRT) software.
- Subjects were seated comfortably in a room with adequate light and silent atmosphere in front of a computer laptop.
- A laptop computer with a vertical refresh rate of 60Hz or better with a pixel response time of 5ms or faster was used.
- After creating the Subject ID, 8 practice trials were given so as to make the subjects have sound understanding about the task.
- During the trial, the participants had to respond to a stimulus, which was a cross appearing inside a white box. Participant had to respond by pressing any key (preferably the space bar) as quickly as possible. The cross would remain on the screen till the response was recorded, which then disappeared and replaced by a new cross after a period of time according to the set Inter-Stimulus Interval.
- The instruction was: “First of all you will have a practice session. A cross will appear in the box on the screen (x) times and each time it appears you should press any key as quickly as you can. Don’t hold the key down, but press and release it when the cross appears. Use the index finger of your preferred hand to press the key throughout the test. When you are ready, press any key to start.”
- After practice trials, 20 Real-Time Experiment trials were performed.
- The original default settings for the task have been validated and used in previous studies. The same have been utilized for this study. They are as follows: Number of Practice Trials= 8
- Number of Experiment Trials = 20
- Response Range = 150-1500 ms
- Inter Stimulus Interval = 1000-3000 ms
- If a participant holds a key down instead of releasing it, the cross remained on the screen and the next trial did not start until the key was released. Also, if the response fell out of the range, it was not be recorded and was replaced by another trial.
- After the test was completed, a message read “Test Completed Thank You!”
- After saving, the software automatically created 2 Excel Sheets with the Reaction Time (RT) for each subject and trial, and the Mean RT for all the trials for every subject (File Names: SRT_Header, SRT_Detail). The File “SRT_Header” includes the Mean, Median, Variance and Standard Deviation along with other variables for each subject. The Mean Reaction Time is in milliseconds (ms).

Statistical Analysis

- All the data collected was entered in Microsoft® Excel 2007 and statistical analysis was done using SPSS version 15.
- The data was tested for normality using kolmogrove smirnov Test.

- As Cranio-Vertebral Angle (x˚), CCFT activation score (mm hg) and Mean SRT (ms) did not pass the test of normality, correlational analysis was done using a non- parametric statistic test i.e., Spearman's Rank Correlation Coefficient (ρ).

Results and Tables

The mean age group of the study population was 21.01 ± 1.82 years, with 64% participants being females and 36% males. The mean CVA was 51.13 ± 3.81 degrees, mean CCFT activation score was 24.58 ± 2.23 mm hg and mean SRT was 318.47 ± 43.55 ms.

Table 1: Mean and Standard Deviations for Age, Cranio-Vertebral Angle (CVA) and Cranio-Cervical Flexion Test (CCFT) Activation Scores and Simple Reaction Time (SRS)

Variables	Mean	Standard Deviation
Age	21.03	1.82
CVA (Degrees)	51.13	3.81
CCFT Activation Score (mm hg)	24.58	2.23
SRT (MS)	318.47	43.55

- The adjoining figure depicts a pie-chart highlighting the gender distribution in the dataset; 64% (167) participants were females and 36% (93) participants were males.

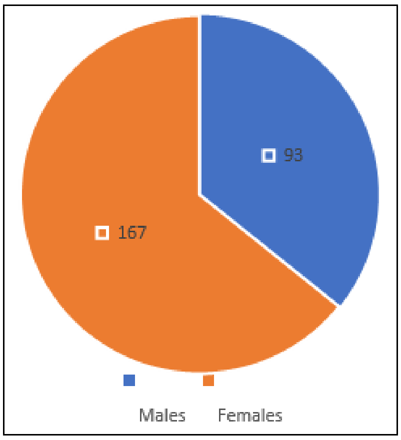
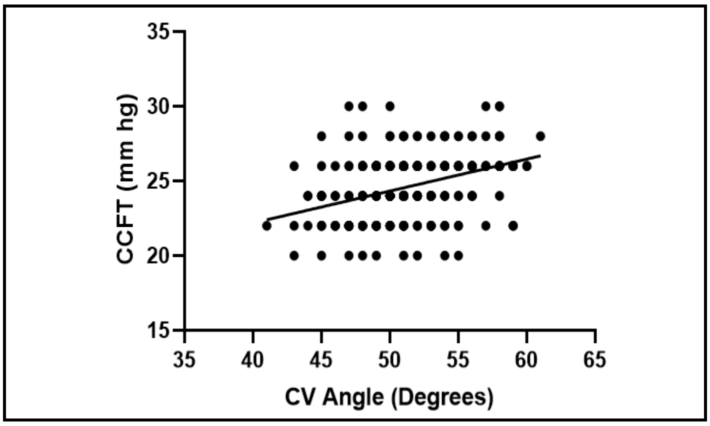


Fig 1

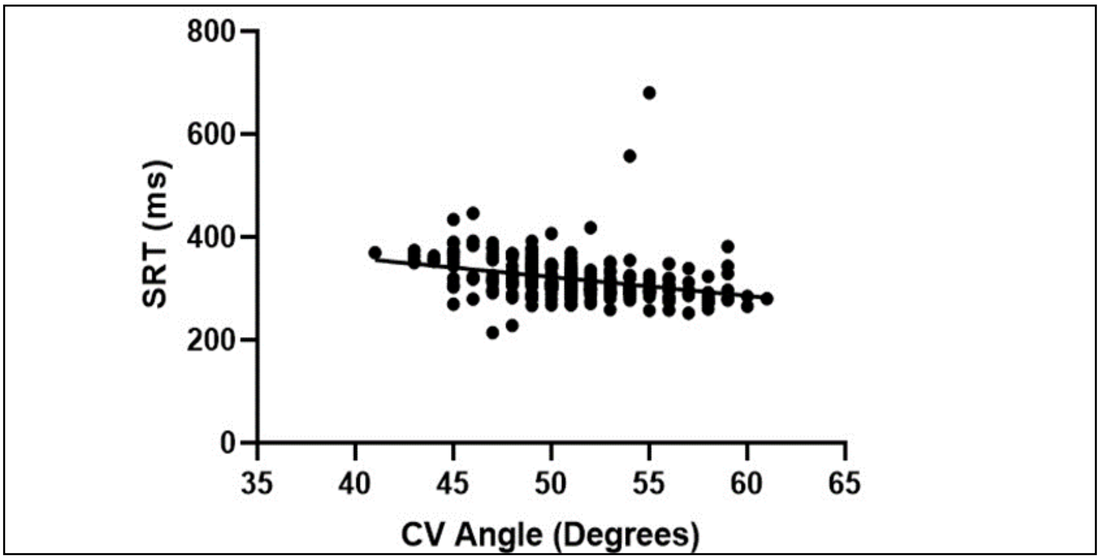
- Non-Parametric analysis was done using Spearman's Rank Correlation Coefficient (ρ) test.
- 95% Confidence interval was used and significance value was set at p = ≤0.05.

Table 2: Correlation between Cranio-Vertebral Angle (CVA) and Cranio-Cervical Flexion Test (CCFT) Activation Scores and Simple Reaction Time (SRS)

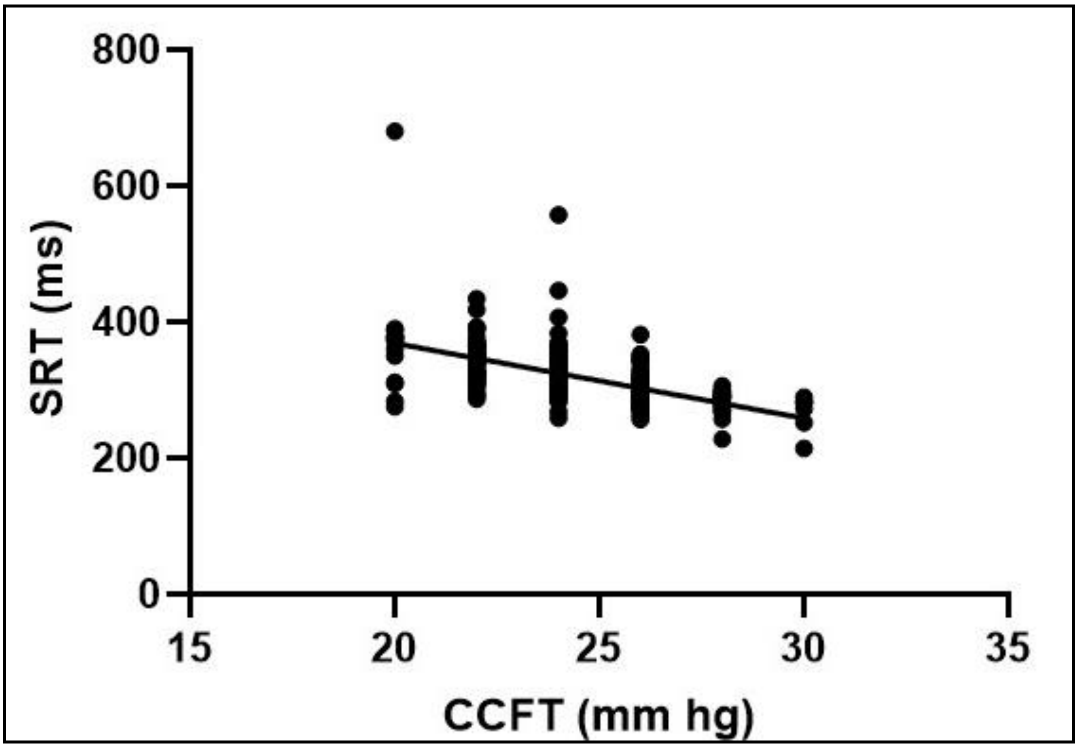
Variables	Spearman's co -Coeffiv	P value	Significance
CVA and CCFT	ρ = 0.3541	<0.0001	Statistically Significant
CVA and SRT	ρ = -0.4727	<0.0001	Statistically Significant
CCFT and SRT	ρ = -0.6787	<0.0001	Statistically Significant



Graph 1: Correlation between Cranio-Vertebral Angle and Cranio-Cervical Flexion Test



Graph 2: Correlation between Cranio-Vertebral Angle and Simple Reaction Time



Graph 3: Correlation between Cranio-Cervical Flexion Test and Simple Reaction Time

Discussion

This study revolved around 260 participants with an aim of assessing a correlation between cervical posture, deep cervical flexor muscle endurance and simple reaction time. The mean age group of the study population was 21.01 ± 1.82 years, with 64% participants being females and 36% males. The mean CVA was 51.13 ± 3.81 degrees, mean CCFT activation score was 24.58 ± 2.23 mm hg and mean SRT was 318.47 ± 43.55 ms.

Relationship between Head Posture and Deep Cervical Flexor Muscle Endurance

According to Table 1, Correlational analysis between cranio-vertebral angle (CVA), which is a measure of cervical spine posture and cranio-cervical flexion test (CCFT) activation scores, a measure of deep cervical flexor endurance, shows a weak positive relationship between the two variables *(*$\rho = 0.3541, p < 0.0001$*).*

This suggests that, with a reduction in CVA (and hence an associated forward head posture), there might be a subtle but definite associated reduction in the activation score of the deep cervical flexor muscles, and vice versa. Conversely, good postural alignment might be associated with better CCFT activation scores, and thus, better muscle endurance. A possible explanation for a positive correlation between head posture and deep cervical flexor muscle endurance in this study can be as follows: The posture committee of the American Academy of Orthopaedic Surgeons (AAOS) defines good posture as "The state of muscular and skeletal balance which protects the supporting structures of the body against injury or progressive deformity, irrespective of the position (erect, lying, squatting or stooping) in which these structures are working or resting [12]."

Dejectedly, with an ever-increasing population working on visual display terminals of phones and laptops, especially in a non-ergonomic environment, the universality of faulty postural patterns has increased. In a cross-sectional study done by Sutantar Singh et. al. on the Prevalence of forward head posture and its impact on the activity of daily living among students of Adesh University, India, the authors observed a 73% prevalence of Forward Head Posture (FHP) in students, most of which were asymptomatic[18] Such high prevalence can be explained by the fact that it is more common to use smartphones and other visual display terminals in the leaning forward posture [19].

With FHP, associated hyper-lordosis increases the length of the external moment arm by shifting the centre of gravity (CoG) anterior to the weight bearing axis [20] leading to persistent contraction of the extensors, and an associated lengthening & weakness of the anterior flexors. These biomechanical changes directly influence thickness of the muscles of the cranio-cervical area as well as reduction in the functional activity of the same.

The fibre composition of a muscle typically encompasses percentage of different muscle fibre types, which can be divided as type I, IIa and IIb. Type 1 fibres are "slow twitch fibres" with high oxidative low-glycolytic capacity with reasonable resistance to fatigue. Type IIb, the "fast twitch fibres" are the low oxidative-high glycolytic fibres which are prone to fatigue. Type IIa fibres generally include the properties of both I and IIb. Given their postural function, muscles of the spine have greater proportion of type 1 fibres [21].

Even though muscle fibre composition is principally set on genetic factors, activity is thought to alter the composition. In a study done by Joseph K. et. al. on "Relationship between muscle fibre composition and functional capacity of back muscles in healthy subjects and patients with back pain", the authors observed muscle fibre atrophy and conversion of fibre type from slow to fast twitch fibres with disuse.[21] Sub-Occipital muscles are known to contain a large number of muscle spindles, and are important structures maintaining the stability of the cervical spine, by controlling head movements & posture. It is observed that atrophy of sub-occipital muscles lead to postural instability [22]. FHP can also induce constraints to functional movement of the cervical spine. It is also reported that chronic maintenance of FHP can cause a reduction in the number of sarcomeres and shortening of muscular fibres around the atlanto-occipital joint.[9]

It is known that FHP retains the cervical spine in flexion and increases extension at cranio-cervical region, resulting in significantly shorter sub-occipitals, decreased activation of deep cervical flexors and increase in thickness of sternocleidomastoid muscles. As the deep cervical flexor muscle endurance directly influences the function of cervical spine, it is important in maintaining posture & stability [22]. With FHP adapted for a prolonged period of time, the associated muscle imbalances due to altered length-tension relationship results in overactivity of the superficial muscles; prolonged activity of which results in disuse atrophy of the deep segmental muscles. This factor is also considered to be associated with the onset and progression of dyspragia in the cervical region. Studies have also observed that the posture of the cervical spine affects the endurance rather than the strength of the deep neck flexor muscle group [23].

Also, correlating physical impairments, pain, disability and patient satisfaction in patients with chronic neck pain, Chiu et. al. in 2005, reported that maintaining such faulty alignments increase the load on the non-contractile structures, resulting in atypical stresses on the posterior cranio-cervical area, which can lead to myofascial pain.[24] Research has also shown that patients with cervical pain often present with reduced activation of the deep cervical flexors during cranio-cervical flexion as well as delayed activation during postural perturbations, with an associated reduction in endurance [15, 25, 26]. This explains the correspondence between poor deep cervical flexor performance and associated postural malalignments, which was observed in this study. Moreover, the coefficient of determination (R^2) for the relationship between CVA and CCFT reveals that 12.5% of deep neck flexor performance (CCFT) could be attributed to the neck posture (CVA°).

Relationship between Head Posture and Visual Reaction Time

According to Table 1, correlational analysis between CVA, measure of cervical spine posture (FHP) and SRT, a measure of reaction time shows a weak-to-moderate negative relationship between head posture and reaction time ($\rho = -0.4727, p < 0.0001$). This suggests that, with a reduction in CVA (FHP) there might be an increase (i.e., delay) in the reaction responses. A viable explanation for this relationship can be as follows. In a study done on "Emergence of postural patterns as a function of vision and translation frequency", Buchanan et. al. observed that fixing the head & trunk in space achieves significant functional tasks including gaze stabilization and stabilization of centre of mass of the head & trunk, as well as minimizes external stresses [27].

Spatial Orientation is a baseline strategic process required for normal functioning and coordination of movement, as well as maintenance of posture [28] and according to Dornan et. al., visual recognition is a key factor in maintaining posture and balance in the static conditions [29]. In a review on "Reflex control of the spine and posture", Morningstar et. al observed that while reflexive components for postural control are found throughout the body, majority of the postural mechanisms are housed in the vicinity of the head and neck. Visual, vestibular as well as joint & soft tissue mechanoreceptors are paramount contributors in the maintenance and regulation of posture, and that, each of these afferents detect and respond to various types of perturbations, each with its own specific pathway of communication with the higher centres [30].

The cervical spine is a literal depository of afferent integration. Various anatomic structures in this region are collectively responsible for maintaining optimal head on neck alignment, including facet joint & capsule, ligaments and anterior & posterior musculature.[30] Facet joints of the cervical spine harbours a number of mechanoreceptors, which are together responsible in providing afferent input to higher centres. A significant number of free nerve endings and pacinian corpuscles are also found in facet joint capsules, which are notable contributors in providing rapid adaptations & stabilisation in various positions [30].

In a study done by an Sun et. al. on "Radiologic assessment of forward head posture and its relation to myofascial pain syndrome" [31] the authors observed that with forward head posture, excessive compressive of the facet articulation and capsular ligament strain stretches the anterior structures while shortening the posterior muscles, which could damage the synovial folds. Also, by the virtue of oblique joint facet joint planes, FHP might increase the compressive forces between the articular cartilages.

Vertebrae of the cervical spine have significant contribution to afferent proprioceptive input as well, which serve to correct malalignments and play a pivotal role in postural control, as well as maintenance of fine movements of the head in coordination with the inputs from visual and vestibular system, and that with asymmetric alignment of head-neck, there are variable errors in the afferent inputs [32]. Abnormal head-neck alignment is the root cause of many neuro-musculo-skeletal impairments. In a cross-sectional study done by Moustafa et. al. the authors observed a strong correlation between head posture (CVA) and cervical sensorimotor control, in that, FHP negatively influenced cervical sensorimotor control as well as the autonomic nervous system [33].

As Sensorimotor dysfunction is found to have a negative influence on hand-eye coordination [34], FHP can possibly play a pivotal role in affection of visual reaction time, due to the abundance of mechanoreceptors in the facets as well as capsule-ligamentous structures in the cervical spine, which was observed in this study. Furthermore, the coefficient of determination (R^2) for the relationship between head posture and visual reaction time suggests that 22.3 % of visual reaction time scores (SRT) could be accounted to the neck alignment (CVA°).

Relationship between Deep Cervical Flexor Muscle Endurance and Visual Reaction Time

Correlational analysis between CCFT activation scores, a measure of deep cervical flexor muscle endurance and SRT, a measure of reaction time shows a moderate-to-strong negative relationship between the two variables *($\rho = -0.6787$, $p < 0.0001$).* This suggests that, poor CCFT activation scores (i.e., Poor Deep Cervical Flexor Muscle Endurance) are associated with a significant increase (i.e., delay) in the response times. Conversely, better endurance of the deep cervical flexor muscles might result in faster reaction responses. A possible explanation for this relationship might the upper cervical spine is the most mobile part of vertebral column, which comes at the expense of mechanical stability. The deep flexor muscles of the cervical spine play a crucial role in maintenance of stability. Proprioception provides sensory feedback to the higher centres, contributing to maintaining optimal body alignment; cervical musculature has higher muscle spindle density, and therefore plays a key role in providing the proprioceptive sensory information [35]. The upper cervical spine is also found to have more connections with the visual and vestibular systems, contributing more to reflex activity [36, 37].

While using a visual display terminal, a typical user tends to angle their head and neck more forward, thus resulting in abnormal alignment of the head and neck, FHP being the commonest one [38]. FHP is associated with mechanical deformations of the cervical joints, vertebrae as well as of the muscles involved in postural control [32] Along with many other impairments, FHP is known to result in significant increase in the bending torque of surface neck flexor muscles [39]. In a study done by Ishida et. al. on "Correlation between neck slope angle and deep cervical flexor muscle thickness in healthy participants", the authors observed that the thickness of the longus colli muscle decreased as the angle of FHP decreased, which suggested that FHP associated changes in the posture results in disuse of the deep neck flexor muscles [40].

In a study done by Lee et. al on "Characteristics of Cervical Position Sense in Subjects with Forward Head Posture", the authors observed that the relative changes in the length of the muscles due to altered alignment can have a negative effect on muscle spindle activity involved in proprioception, highlighting as variable errors in joint position sensing [41]. With postural malalignments and associated changes in the structure & function of the deep cervical flexors, there are several mechanisms that could alter cervical afferent activity. Sensitivity of the receptors of the spine can be affected by impairments of the soft tissues, including fatigue, fibre transformation, fatty infiltration and disuse atrophy of the muscles, which can alter their proprioceptive potential. Afferent input can also be affected by chemical changes brought by ischemic or inflammatory events [35] as well as reflex inhibition of gamma motor neurons, which results in incorrect afferents from muscle spindles to the CNS with a consequence of altered proprioception sense [28].

Clinical researchers have demonstrated that insufficiency in the activation of the deep cervical muscles, altered motor control recruitment patterns and muscle fatigue can also contribute to proprioceptive dysfunction. Similar impairment patterns are seen in many patients with neck pain [35]. In an RCT done by Marwa Shafiek Mustafa Saleh et. al. on "Effect of deep cervical flexors training on neck proprioception, pain, muscle strength and dizziness in patients with cervical spondylosis", the authors observed impairments in positioning consistency as well as postural malalignments with dysfunction in performance of the deep muscles of the cervical spine [42].

As pertinent proprioceptive feedback is obligatory for rapid processing of visual feedback [43], visual reaction responses can be delayed with spindle dysfunction associated with poor muscle function, which is in turn a result of poor postural alignment, which was observed in this study. In addition, the coefficient of determination (R^2) for the relationship between deep neck flexor performance and visual reaction time suggests that 46.06 % of visual reaction time scores (SRT) could be dependent on deep neck flexor performance (CCFT).

Conclusion

There is a weak positive, weak-to-moderate negative and moderate-to-strong negative correlation exist between head posture and deep cervical flexor muscle, head posture and visual reaction time and deep cervical flexor muscle endurance and visual reaction time respectively in young healthy adults.

References

1. M Dena Gardiner, The Principles of Exercise Therapy, Fourth Edition, Part IV Topic 18; Posture, 245.
2. Carini F, Mazzola M, Fici C, Palmeri S, Messina M, Damiani P, *et al*. Posture and posturology, anatomical and physiological profiles: overview and current state of art. Acta Bio Medica: Atenei Parmensis.,2017:88(1):11.
3. Bernard BP, Putz-Anderson V. Musculoskeletal disorders and workplace factors; a critical review of epidemiologic evidence for work-related musculoskeletal disorders of the neck, upper extremity, and low back.
4. Di Fabio RP, Emasithi A. Aging and the mechanisms underlying head and postural control during voluntary motion. Physical Therapy.,1997:77(5):458-75.
5. Subbarayalu AV, Ameer MA. Relationships among head posture, pain intensity, disability and deep cervical flexor muscle performance in subjects with postural neck pain. Journal of Taibah University medical sciences.,2017:12(6):541.
6. Contractor ES, Shah SS, Shah SJ. To study correlation between neck pain and cranio- vertebral angle in young adults. Int Arch Integr Med.,2018:5(4):81-6.
7. Liu JX, Thornell LE, Pedrosa-Domellöf F. Muscle spindles in the deep muscles of the human neck: a morphological and immunocytochemical study. Journal of Histochemistry & Cytochemistry.,2003:51(2):175-86.
8. Lee KJ, Han HY, Cheon SH, Park SH, Yong MS. The effect of forward head posture on muscle activity during neck protraction and retraction. Journal of physical therapy science.,2015:27(3):977-9.
9. Kim DH, Kim CJ, Son SM. Neck pain in adults with forward head posture: effects of craniovertebral angle and cervical range of motion. Osong public health and research perspectives.,2018:9(6):309.
10. Falla DL, Jull GA, Hodges PW: Patients with neck pain demonstrate reduced EMG Activity of deep cervical flexor muscles during performance of cranio-cervical flexion tests; Spine 29, 2018, 2114, 2004.
11. Kotwani S, Bid DN, Ghatamaneni D, Alahmari KA, Ramalingam T, Paul Silvian S. Determining the reliability of craniocervical flexion test in asymptomatic individuals. Hong Kong Physiotherapy Journal.,2018:38(01):33-40.
12. Hazar Z, Karabicak GO, Tiftikci U. Reliability of photographic posture analysis of adolescents. Journal of physical therapy science.,2015:27(10):3123-6.
13. Dimitriadis Z, Podogyros G, Polyviou D, Tasopoulos I, Passa K. The reliability of lateral photography for the assessment of the forward head posture through four different angle-based analysis methods in healthy individuals. Musculoskeletal care.,2015:13(3):179-86.
14. Singla D, Veqar Z. Methods of postural assessment used for sports persons. Journal of clinical and diagnostic research: JCDR.,2014:8(4): LE01.
15. Jull GA, O'leary SP, Falla DL. Clinical assessment of the deep cervical flexor muscles: the craniocervical flexion test. Journal of manipulative and physiological therapeutics.,2008:31(7):525-33.
16. Shankar P, Desai MS, Honkalas P, Kumar A. Determination of simple reaction time in individuals with cervical spondylosis. Int J Physiother Res.,2018:6(3):2701-04.
17. Deary IJ, Liewald D, Nissan J. A free, easy-to-use, computer-based simple and four- choice reaction time programme: the Deary-Liewald reaction time task. Behavior research methods.,2011:43(1):258-68.
18. Singh S, Kaushal K, Jasrotia S. Prevalence of forward head posture and its impact on the activity of daily living among students of Adesh University–A cross-sectional study. Adesh University Journal of Medical Sciences & Research.,2020:2(2):99-102.
19. Kang JH, Park RY, Lee SJ, Kim JY, Yoon SR, Jung KI. The effect of the forward head posture on postural balance in long time computer-based worker. Annals of rehabilitation medicine.,2012:36(1):98.
20. Edmondston SJ, Sharp M, Symes A, Alhabib N, Allison GT. Changes in mechanical load and extensor muscle activity in the cervico-thoracic spine induced by sitting posture modification. Ergonomics.,2011:54(2):179-86.
21. Ng JK, Richardson CA, Kippers V, Parnianpour M. Relationship between muscle fiber composition and functional capacity of back muscles in healthy subjects and patients with back pain. Journal of Orthopaedic & Sports Physical Therapy.,1998:27(6):389-402.
22. Hong JH, Lee DH, Kim SE, Seo DK. Correlation between contraction ratio, endurance, and muscle tone of cervical muscles. Physical Therapy Rehabilitation Science.,2020:9(4):302-8.
23. Gong W, Kim C, Lee Y. Correlations between cervical lordosis, forward head posture, cervical ROM and the strength and endurance of the deep neck flexor muscles in college students. Journal of Physical Therapy Science.,2012:24(3):275-7.
24. Chiu TT, Lam TH, Hedley AJ. Correlation among physical impairments, pain, disability, and patient satisfaction in patients with chronic neck pain. Arch Phys Med Rehabil.,2005:86(3):534-40.

25. Schomacher J, Falla D. Function and structure of the deep cervical extensor muscles in patients with neck pain. Manual therapy,2013:18(5):360-366.
26. O'Leary S, Falla D, Elliott J M, Jull G. Muscle dysfunction in cervical spine pain: implications for assessment and management. journal of orthopaedic & sports physical therapy,2009:39(5):324-333.
27. Buchanan JJ, Horak FB. Emergence of postural patterns as a function of vision and translation frequency. J Neurophysiol.,1999:81(5):2325-39. doi: 10.1152/jn.1999.81.5.2325. PMID: 10322069.
28. Reddy RS, Alahmari KA. Cervical proprioception evaluation using cervical range of motion device: A narrative review. Saudi Journal of Sports Medicine.,2015:15(2):127.
29. Dornan J, Fernie GR, Holliday PJ. Visual input: its importance in the control of postural sway. Archives of physical medicine and rehabilitation.,1978:59(12):586-91.
30. Morningstar MW, Pettibon BR, Schlappi H, Schlappi M, Ireland TV. Reflex control of the spine and posture: a review of the literature from a chiropractic perspective. Chiropractic & osteopathy.,2005:13(1):1-7.
31. Sun A, Yeo HG, Kim TU, Hyun JK, Kim JY. Radiologic assessment of forward head posture and its relation to myofascial pain syndrome. Annals of rehabilitation medicine.,2014:38(6):821.
32. Ha SY, Sung YH. A temporary forward head posture decreases function of cervical proprioception. Journal of exercise rehabilitation.,2020:16(2):168.
33. Moustafa IM, Youssef A, Ahbouch A, Tamim M, Harrison DE. Is forward head posture relevant to autonomic nervous system function and cervical sensorimotor control? Cross sectional study. Gait & posture.,2020:77:29-35.
34. Sittikraipong K, Silsupadol P, Uthaikhup S. Slower reaction and response times and impaired hand-eye coordination in individuals with neck pain. Musculoskeletal Science and Practice.,2020:50:102273.
35. Kristjansson E, Treleaven J. Sensorimotor function and dizziness in neck pain: implications for assessment and management. journal of orthopaedic & sports physical therapy.,2009:39(5):364-77.
36. Kulkarni V, Chandy MJ, Babu KS. Quantitative study of muscle spindles in suboccipital muscles of human foetuses. Neurol India.,2001:49:355-359.
37. Liu JX, Thornell LE, Pedrosa-Domellöf F. Muscle spindles in the deep muscles of the human neck: a morphological and immunocytochemical study. J Histochem Cytochem,2003:51:175-186.
38. Kim EK, Kim SG. Forward head posture (FHP) angle and plantar pressure resulting from oscillatory stimulation training of the shoulder joint: a randomized controlled trial. J Back Musculoskelet Rehabil,2019:32:37-42.
39. Vasavada AN, Li S, Delp SL. Influence of muscle morphometry and moment arms on the moment-generating capacity of human neck muscles. Spine (Phila Pa 1976),1998:23:412-422.
40. Ishida H, Suehiro T, Kurozumi C, Ono K, Ando S, Watanabe S. Correlation between neck slope angle and deep cervical flexor muscle thickness in healthy participants. Journal of bodywork and movement therapies.,2015:19(4):717-21.
41. Lee MY, Lee HY, Yong MS. Characteristics of cervical position sense in subjects with forward head posture. Journal of physical therapy science.,2014:26(11):1741-3.
42. Saleh MS, Rehab NI, Sharaf MA. Effect of deep cervical flexors training on neck proprioception, pain, muscle strength and dizziness in patients with cervical spondylosis: A randomized controlled trial. Phys Ther Rehabil.,2018:5(1):14.
43. Balslev D, Miall RC, Cole J. Proprioceptive deafferentation slows down the processing of visual hand feedback. Journal of vision.2007:7(5):12-.